

REMARKS

The following responds to the rejections set forth by the Examiner in the Final Office Action of February 22, 2007. In the Final Office Action, the Examiner rejects claims 1-3, 6, 8, 9, 11-14, 26-28, and 55-58, objects to claim 10, and allows claims 59-62. As a preliminary matter, Applicants thank the Examiner for the allowance of claims 59-62. Claim 55 has been amended and claims 26 and 27 have been cancelled. Claims 29-54 have been previously withdrawn. Claims 1-3, 6, 8-14, 28, and 55-62 remain pending in this application.

I. Claim Rejections Under 35 U.S.C. § 102(b)

In the Final Office Action of February 22, 2007, the Examiner rejected claims 1-3 and 8 as being anticipated under 35 U.S.C. § 102(b) by U.S. Publication No. 2002/0076929, published on June 20, 2002 by Lu et al. (hereinafter “Lu”). Applicants respectfully traverse the Examiner’s grounds for rejection.

Claim 1 is directed to a method for depositing copper overlying a work piece. The method comprises the steps of depositing overlying the work piece a barrier layer having a surface, forming a protective layer that overlies the surface of the barrier layer and that inhibits oxidation of the surface, removing the protective layer, and, after removing the protective layer, electrochemically depositing copper overlying the barrier layer.

In contrast, Lu does not disclose a method for depositing copper that includes forming a protective layer that overlies a barrier layer and that inhibits oxidation of the barrier layer surface and then removing that protective layer before electrochemically depositing copper. The Examiner asserts that the seed layer 112 of Lu functions as a protective layer and then refers to paragraph [0018] for support that Lu discloses removing the seed layer. However, paragraph [0018] does not disclose removing the seed layer 112 but, rather, refers to a plasma treatment on the surface of the seed layer for the removal of surface contaminants 122 and the reduction of any CuOx 123. In fact, according to Lu, the presence of the seed layer is very important for the electrochemical deposition (ECD) of copper. As stated in Lu, “In order for the ECD process to proceed, a seed layer is required to pass current and to serve as a nucleation layer.” (Paragraph

[0006]) The fact that the seed layer is not removed is also evident by paragraph [0022], which refers to the subsequent deposition of copper and which states: “After placing the wafer in the plating solution, a current of approximately 0.75 Amps is passed through the seed layer 112 for a time on the order of 15 secs.” If the seed layer had been removed, as asserted by the Examiner, no current could be passed through it, as directed by paragraph [0022], to facilitate the deposition of copper.

The plasma treatment in Lu does not remove the seed layer but, rather, reduces the oxide on the seed layer surface to remove the oxygen atoms, leaving the seed layer behind. The reduction reaction occurs according to the following chemical equation:



Thus, the copper seed layer remains, the oxide is removed, and the ECD process may continue by passing a current through the seed layer, as described in Lu. And, as reason dictates, the oxygen atoms on the seed layer cannot be considered a protective layer that inhibits oxidation of the barrier layer surface because it is the very oxidation that the protective layer of the instant application is used to inhibit. Accordingly, Lu does not disclose removal of the seed layer 112 or any other protective coating that inhibits oxidation of a barrier layer. Thus, as Lu does not disclose every element of amended claim 1, it does not anticipate amended claim 1, or claims 2-3, and 8 that depend therefrom.

II. Claim Rejections Under 35 U.S.C. § 102(e)

In the Final Office Action, the Examiner rejected claims 28 and 55-57 as being anticipated under 35 U.S.C. § 102(e) by U.S. Patent 7,135,404 B2, issued on November 14, 2006 to Baskaran et al. (hereinafter “Baskaran”). Applicants respectfully traverse the Examiner’s grounds for rejection.

Independent claim 55 has been amended to include the elements of claims 26 and 27 and claims 26 and 27 have been cancelled. Amended claim 55 is directed to a method for depositing copper overlying a work piece. The method comprises depositing overlying the work piece a barrier layer having a surface. The barrier layer is exposed to a copper plating solution and a contaminant, an oxide, or both is removed from the barrier layer by applying to the surface an initial cathode current pulse of no less than

about 25 mA/cm² for about 0.5 to about 10 seconds such that no substantial amount of copper is deposited on the barrier layer. After the step of apply an initial cathode current pulse, copper is electrochemically deposited overlying the barrier layer.

In contrast, Baskaran does not teach applying an initial cathode current “pulse” of no less than about 25 mA/cm² for about 0.5 to about 10 seconds. Rather, Baskaran teaches a “cathodic treatment” using current densities of 10 mA/cm² or higher for time periods from about 15 seconds to a minute. [Col. 10, lines 1-5] In Baskaran, when the alkaline or acidic solution is a plating bath, “the cathodic treatment can be performed just below the deposition potential of the electroplating bath solution,” instead of above the deposition potential as in the instant application. [Col. 10, lines 21-27] According to Dr. Roey Shaviv, Senior Technologist and IP Executive of Novellus Systems, Inc., assignee of the present application, the fact that Baskaran teaches the use of a low cathode current for longer time is an important difference from the invention of the instant application. (Declaration of Dr. Roey Shaviv (hereinafter “Shaviv Decl.”), paragraph 5) Pursuant to the laws of thermodynamics, the amount of contaminant material (typically organic residues) and/or oxides that is removed from the barrier layer surface during application of a current is proportional to the amount of current that passes between the reactants. In other words, the integral under the current versus time curve ($\int_{t=0}^{t=\Delta t} I \cdot dt$) determines the amount of reaction that takes place. The difference is in the kinetics. When a reactant is a contaminant or dielectric (such as a metal oxide), the activation energy is higher than when the reactant is a conductor. Applying a “pulse” of no less than about 25 mA/cm² for about 0.5 to about 10 seconds overcomes the threshold to the reaction as defined by the activation energy. The dielectric metal oxide or contaminants thus react faster than if a lower current is applied. The use of a cathode current having a magnitude of only 10 mA/cm² is too low to provide adequate removal of the contaminants and/or oxides unless applied for a significantly long period of time. This long time period would be significantly inefficient and would adversely affect product throughput. (Shaviv Decl., para. 6)

Further, according to Dr. Shaviv, if the cathodic treatment of Baskaran were conducted at a higher current, such as 25 mA/cm² as taught by the instant application, for 15 seconds or more, as taught by Baskaran, the effects may be detrimental. It is desirable

to carefully control the electrodeposition of copper in a work piece feature to insure uniform bottom-up deposition, that is, deposition without a significant amount of voids and/or defects and to insure that small dimensioned features are filled at substantially the same rate as large dimensioned features. (Shaviv Decl., para. 7) For example, one embodiment discussed in the instant application discloses the use of an initial cathodic current pulse having a magnitude of 25-200 mA/cm² for about 0.5 to 3 seconds (to remove contaminants and/or oxides), followed by a reduction in the cathodic current to a magnitude of about 1 to about 10 mA/cm² to initiate copper deposition. The cathodic current then may be increased as needed to complete deposition. (Paragraph [0030]) However, the cathodic treatment of Baskaran that uses such high current for a long amount of time may result not only in the removal of the contaminants and oxides but also in a quick and, thus, less controllable electrodeposition of copper for the remaining time. A less controllable electrodeposition process can result in a lower quality copper fill, which can adversely affect device operation. (Shaviv Decl., para. 7) In addition, a pulse of no more than 10 seconds is 50% faster than an electrolytic treatment of 15 seconds. This increase in process time provides a significant production advantage. (Shaviv Decl., para. 8)

Accordingly, Baskaran does not disclose applying an initial cathode current “pulse” of no less than about 25 mA/cm² for about 0.5 to about 10 seconds such that no substantial amount of copper is deposited on the barrier layer. Thus, as Baskaran does not disclose every element of amended claim 55, it does not anticipate amended claim 55, or claims 28, and 56-57 that depend therefrom.

III. Claim Rejections Under 35 U.S.C. § 103(a)

In the Office Action, the Examiner rejected claims 6 and 11 as being unpatentable over Lu. The Examiner asserts that, while Lu does not disclose a protective layer having a thickness of no greater than about 20 angstroms, such element is obvious. Applicants respectfully traverse the Examiner’s rejections.

Claims 6 and 11 depend from claim 1. For a claim to be properly rejected for obviousness, the Examiner must show that the subject matter sought to be patented would have been obvious to one of ordinary skill in the art at the time the invention was made.

As described above, Applicants respectfully submit that a *prima facie* case of obviousness has not been made out by the Examiner with respect to amended claim 1, and hence claims 6 and 11 that depend therefrom, because every critical element appearing in the claims is not disclosed by Lu. Thus, claims 6 and 11 are not rendered obvious by Lu.

In the Office Action, the Examiner rejected claims 26 and 27 as being unpatentable over Lu. Claims 26 and 27 have been cancelled and, thus, the Examiner's rejections have been rendered moot.

The Examiner also rejected claim 9 as being unpatentable over Lu in view of U.S. Patent Publication 2002/0076929 to Jung et al., published November 26, 2002 (U.S. Patent No. 6,486,055) (hereinafter "Jung"). Claim 9 depends from claim 8, which depends from claim 1. As explained above, Lu does not disclose a method for depositing copper that includes forming a protective layer that overlies a barrier layer and that inhibits oxidation of the barrier layer surface and then removing that protective layer before electrochemically depositing copper. Jung also does not disclose a method for depositing copper that includes forming a protective layer that overlies a barrier layer and that inhibits oxidation of the barrier layer surface and then removing that protective layer before electrochemically depositing copper. Accordingly, Applicants respectfully submit that a *prima facie* case of obviousness has not been made out by the Examiner with respect to claim 9 because every critical element appearing in the claim is not disclosed by Lu in view of Jung.

The Examiner further rejected claim 12 as being unpatentable over Lu in view of U.S. Patent 6,436,267 B1 issued on August 20, 2002 to Carl et al. (hereinafter "Carl"). Claim 12 depends from claim 1. As explained above, Lu does not disclose a method for depositing copper that includes forming a protective layer that overlies a barrier layer and that inhibits oxidation of the barrier layer surface and then removing that protective layer before electrochemically depositing copper. Carl also does not disclose a method for depositing copper that includes forming a protective layer that overlies a barrier layer and that inhibits oxidation of the barrier layer surface and then removing that protective layer before electrochemically depositing copper. Accordingly, Applicants respectfully submit that a *prima facie* case of obviousness has not been made out by the Examiner with

respect to claim 1, and hence claim 12, because every critical element appearing in the claim is not disclosed by Lu in view of Carl.

The Examiner also rejected claims 13 and 14 as being unpatentable over Lu in view of U.S. Patent Publication 2003/0068887 A1 published April 10, 2003 by Shingubara et al. (hereinafter "Shingubara"). Claim 13 depends from claim 1, and claim 14 depends from claim 13. As explained above, Lu does not disclose a method for depositing copper that includes forming a protective layer that overlies a barrier layer and that inhibits oxidation of the barrier layer surface and then removing that protective layer before electrochemically depositing copper. Shingubara also does not disclose a method for depositing copper that includes forming a protective layer that overlies a barrier layer and that inhibits oxidation of the barrier layer surface and then removing that protective layer before electrochemically depositing copper. Accordingly, Applicants respectfully submit that a *prima facie* case of obviousness has not been made out by the Examiner with respect to claim 1, and hence claims 13 and 14, because every critical element appearing in the claim is not disclosed by Lu in view of Shingubara.

In the Office Action, the Examiner also rejected claim 58 as being unpatentable over Baskaran in view of Carl. Claim 58 depends from claim 55. As described above, Baskaran does not disclose applying an initial cathode current pulse to the surface of the barrier layer. Carl also does not disclose applying an initial cathode current pulse to the surface of the barrier layer. Accordingly, Applicants respectfully submit that a *prima facie* case of obviousness has not been made out by the Examiner with respect to claim 55, and hence 58, because every critical element appearing in the claim is not disclosed by Baskaran in view of Carl.

IV. Conclusion

In view of Applicants' amendments and remarks, it is respectfully submitted that the Examiner's rejections under 35 U.S.C. §§ 102 and 103(a) have been overcome. Accordingly, Applicants respectfully submit that the application, as amended, is now in condition for allowance, and such allowance is therefore earnestly requested. Should the Examiner have any questions or wish to further discuss this application, Applicants request that the Examiner contact the Applicants' attorneys at the below-listed number.

If for some reason Applicants have not requested a sufficient extension and/or have not paid a sufficient fee for this response and/or for the extension necessary to prevent abandonment on this application, please consider this as a request for an extension for the required time period and/or authorization to charge Deposit Account No. 50-2091 for any fee which may be due.

Respectfully submitted,

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